DETECTABILITY OF HIGH-CONDUCTIVITY PLATES BY THE CSAMT METHOD ON BASIS OF ANALOGUE MODELLING RESULTS*

An interesting analogue modelling experience

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In the CSAMT method it is very rare that in the anomaly maps the pure geometry of the model would be directly reflected. In an analogue model experiment 3-D thin-sheet like graphite plates were put on the salt water/high resistivity bottom boundary and amplitude and phase of the electric component parallel to a distant HED transmitter were measured. The position of the phase anomaly proved to be stable in the whole period range (i.e. in the wave-, the transition-, and in the quasi-near zones) serving a correct basis for the interpretation. The amplitude maps were more variable and unusual behaviour was discovered in a narrow period range (that is at the very beginning of the evolution of the long-period anomaly): the small changes over the 3-D thin-sheet like plate were found in an unbelievable close relation with the real shape of the model, leading to much better detectability, than at any other periods. In spite of that this effect in the field in most cases would be masked by measuring errors, this experiment is a clear proof that we must pay more attention to such transition phenomena.

Keywords: analogue modelling; controlled source methods; electromagnetic methods; horizontal electric dipole; three-dimensional problem

INTRODUCTION

In 1989 at the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences CSAMT analogue model experiments were carried out for the Geophysical Exploration Company of the Hungarian Oil and Gas Trust. In the model tank several high-conductivity thin-sheet like plates having the same area but having different geometrical shape were put and the object of the experiment was to find relations between the anomalies and the geometrical shape of the models.

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(A description of the field problem is given by Nagy et al. 1989.)

As a transmitter a distant HED was used and the amplitude and phase of five electromagnetic field components were measured at eight different frequencies. (Later the measurements were limited to the electric components.) The results are summarized in our Research Report (1989). (Other 3-D examples are collected by Nagy and Szarka 1989.) Here only an interesting modelling experience, as a "by-product" of the measurements, is presented.

DESCRIPTION OF THE MODELS

The description of the modelling equipment is discussed in details by Márécz et al. (1986) and Ádám et al. (1981). A plan-view in Fig. 1 shows
- the HED transmitter,
- three different models: a, b and c,
- orientation of the measuring dipole MN,
- the measuring grid.

In Fig. 2 the cross section is shown. Figures 1 and 2 are proportional in all directions.

ABOUT THE DATA USED FOR THE INTERPRETATION

Relative amplitude (amplitude with graphite/amplitude without graphite) and relative phase (phase with graphite - phase without graphite) of the horizontal electric field measured by MN (see Fig. 1) were determined.

Figure 3 shows typical sounding curves at three different measuring sites. (Along the horizontal axis lambda, is the wavelength in salt water and H1 is the depth of the models.) In agreement with 1-D theoretical calculations it can be seen that where the phase reaches its maximum, the amplitude anomaly is practically zero.

We were interested first of all in the "big" amplitude anomalies: in the short-period \( \text{ABS}(E_x) \)-increase (at
Fig. 1. Plan-view of the CSAMT model experiment. AB: current electrodes, MN: measuring dipole for $E_x$, model a: pistol, model b: reversed letter U, model c: letter U
\( \lambda/h_1 = 4-5 \), in the long-period \( \text{ABS}(E_X) \)-decrease, and also in the phase anomaly.

In Fig. 4, 5, 6 and 7 amplitude and phase anomaly maps are shown at a characteristic "short" period and a characteristic "long" period for all the three models. In Fig. 8 the phase anomalies are shown at \( \lambda/h_1 = 5.49 \).

In figures it can be seen that the amplitude anomalies are more variable, while the phase anomalies are more stable. The resolution power in neither case can be stated to be high. Those parts of the model which are perpendicular to the direction of the transmitter, remain hidden.

A SURPRISING RESULT

In a narrow transition zone, where the \( \text{ABS}(E_X) \) anomaly is just changing from its short-period maximum to a more and more important long-period minimum, the \( \text{ABS}(E_X) \) values should be close to 1. Of course, at different sites these values I are
Ex-amplitude anomalies due to a square model

Phase difference due to a square model

Fig. 3. Relative $E_x$ amplitude and phase sounding curves. The anomaly maps were measured at relative wavelengths indicated by the three vertical lines: $\lambda/h_1 = 3.82$ ("short" period), $\lambda/h_1 = 5.49$ (in the "critical" period range), $\lambda/h_1 = 7.77$ ("long" period)
Fig. 4a. $E_x$ phase over model a at short period

Fig. 4b. $E_x$ phase over model b at short period

Fig. 4c. $E_x$ phase over model c at short period
Fig. 5a. $E_x$ amplitude over model a at short period

Fig. 5b. $E_x$ amplitude over model b at short period

Fig. 5c. $E_x$ amplitude over model c at short period
Fig. 6a. $E_x$ phase over model a at long period

Fig. 6b. $E_x$ phase over model b at long period

Fig. 6c. $E_x$ phase over model c at long period
Fig. 7a. $E_x$ amplitude over model a at long period

Fig. 7b. $E_x$ amplitude over model b at long period

Fig. 7c. $E_x$ amplitude over model c at long period
Fig. 8a. $E_x$ phase over model a at the critical period

Fig. 8b. $E_x$ phase over model b at the critical period

Fig. 8c. $E_x$ phase over model c at the critical period
taken up at slightly different periods, depending on the transmitter-receiver distance and the actual conductivity structure. Consequently if we have a map measured at a certain period, slightly different values will belong to different measuring sites. Since at this period the variation over the model is expected to be somewhere at the measuring errors, nobody has paid attention to the details of these small anomalies. Therefore it was a surprise for us to have a really good correlation between the isolines and the shape of the three structures as it is shown in Fig. 9. (E.g. a rotation of the model b by 180 degrees to get the model c is followed by the isolines only at this critical period.)

REMARKS

According to Fig. 9 the evolution of 3-D anomalies takes place in a very exciting way as far as the isolines in the transition zone seem to be closely connected to the geometric shape of the models. It seems that the bigger the anomaly, the worse is the lateral resolution.

Unfortunately this delicate phenomenon in the field is probably masked by measuring errors, hindering any direct application. Further studies (model measurements and comparisons with 3-D numerical results) are needed yet to give satisfactory explanation of the phenomenon. The aim of this paper is just to call the attention to this problem.

REFERENCES


Fig. 9a. $E_x$ amplitude over model a at the critical period

Fig. 9b. $E_x$ amplitude over model b at the critical period

Fig. 9c. $E_x$ amplitude over model c at the critical period
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